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Parsons Engineering Science, Inc.
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24 June 1998

Major Ed Marchand
AFCEE/ERT
3207 North Road, Bldg 532
Brooks AFB, Texas 78235-5363

Subject: Results of Bioventing System Monitoring at Installation Restoration Program (IRP) Site 11, Beale Air Force Base, California
(Contract No. F41624-92-D-8036, Order 17)

Dear Major Marchand:

This letter presents the results of the bioventing system monitoring performed by Parsons Engineering Science, Inc. (Parsons ES) during the week of 13 April 1998 at IRP Site 11, Beale Air Force Base (AFB), California. Soil gas samples were collected and *in situ* respiration testing was performed by Parsons ES to assess the extent of remediation completed during 1 year and 9 months of expanded bioventing system operation. The purposes of this letter are to summarize site and bioventing activities to date, present the results of the most recent respiration testing and soil gas sampling event, and make recommendations based on site data. A site layout and three tables are attached.

SITE/PROJECT HISTORY

IRP Site 11, the Aerospace Ground Equipment (AGE) Maintenance Area, consists of Building 1225, three aboveground storage tanks (ASTs), three oil/water separators, a small pump island, a backfilled underground storage tank (UST) excavation, paved vehicle parking areas, landscaped areas, and unlined drainage channels. A layout of the site is provided in Figure 1. Current and former facilities at Site 11 have been used to support AGE maintenance activities for more than 30 years. Three former USTs at the site were used for the storage of gasoline, diesel, and JP-4 jet fuel.

The primary sources of subsurface contamination at the site include the former USTs and the oil/water separators located along the eastern edge of the site. The former USTs were removed in June 1992 and replaced with the three ASTs. During soil excavation and UST removal operations, soil contamination was observed in the soil beneath all three USTs. The maximum depth of soil excavation was 30 feet below ground surface (bgs); however, the base of the fill material has been observed to be between 15 and 20 feet bgs (Parsons ES, 1995). Some petroleum hydrocarbon-contaminated soil was left in place following UST removal and soil excavation. Maximum concentrations of 6,000 milligrams per kilogram (mg/kg) total petroleum hydrocarbons as diesel (TPH-d), 860 mg/kg total petroleum hydrocarbons as gasoline (TPH-g), 2,900 mg/kg SR-71 jet fuel (JP-7), 1,200 mg/kg test grade jet fuel (JP-TS), 48 mg/kg benzene, and 721 mg/kg total benzene, toluene, ethylbenzene, and xylenes (total BTEX) in soil have been found in the vicinity of the pump island and former USTs (Parsons

AQ401-02-0396

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ES, 1995). In addition, low levels of halogenated volatile organic compounds (HVOCs) have been detected in site soil, soil gas, and groundwater, as well as upgradient and downgradient of the site (Law Environmental, Inc., 1995; Parsons ES, 1995, Beale AFB, 1998). The oil/water separators are believed to be the primary source of HVOC contamination at Site 11 as determined during recent/ongoing investigations of site soil vapor and groundwater. Groundwater at the site is located approximately 85 feet bgs (Beale, 1998).

In order to address the petroleum hydrocarbon contamination remaining in site soils following UST excavation, Parsons ES (formerly Engineering-Science, Inc. [ES]) installed a bioventing pilot test system at Site 11 in April 1993 as part of the AFCEE Bioventing Initiative program (ES, 1993). The purpose of this project was to determine if *in situ* bioventing would be a feasible cleanup technology for remediating the remaining fuel-contaminated unsaturated zone soils near the former UST excavation. The installed pilot-scale bioventing system consisted of one vent well (VW1), three multi-depth monitoring points (VMP1, VMP2, and VMP3), a regenerative blower and blower housing, air supply piping, and electrical service. The VW and VMPs were installed in accordance with procedures described in the protocol document (Hinchee *et al.*, 1992). The VW was screened from 10 to 50 feet bgs based on field evidence of petroleum contamination between 23 and 26 and 38 and 43 feet bgs. Three casing strings and 6-inch screens were installed in each VMP borehole at depths of approximately 24, 30, and 40 feet bgs to provide monitoring points at variable depths, soil types, and contamination levels. An additional casing string/screen was placed approximately 50 feet bgs at VMP2 because of high organic vapor analysis (OVA) readings and the presence of a clay layer at this depth interval. During system startup, the effective radius of oxygen influence was determined to be at least 55 feet for VW1. Further detail on the pilot test procedures and results can be found in the Interim Bioventing Pilot Test Results Report (ES, 1993), and the Completion of One Year Bioventing Test letter results report (AFCEE, 1995).

The 1-year bioventing pilot test was performed by Parsons ES from May 1993 to June 1994 and demonstrated that bioventing is an effective treatment technology for petroleum-contaminated soils present within the unsaturated zone at Site 11. Total volatile hydrocarbon (TVH) and BTEX concentrations in soil vapor were reduced by as much as 4 orders of magnitude. The 1-year monitoring results also indicated that the long-term radius of oxygen influence may be as high as 70 feet for VW1. While reductions similar to those observed in site soil gas following the first year of pilot-scale bioventing were not observed in three confirmatory soil samples collected in July 1994, this is likely due to a heterogeneous distribution of contamination and the inherent variability of limited soil sampling (Parsons ES, 1995). Based on the favorable pilot testing results, IRP Site 11 was included in the AFCEE Extended Bioventing Project for system expansion (Option 4) and 1 year of system operation and monitoring followed by soil gas sampling and *in situ* respiration testing (Option 1). In anticipation of favorable expanded bioventing system Option 1 results, the AFCEE Extended Bioventing Project also provided funding for confirmatory soil sampling and site closure (Option 2), if appropriate.

The expanded bioventing system was installed by Parsons ES between May 28 and July 8, 1996. The system was installed in accordance with the final work plan (Parsons ES, 1995) and design package (Parsons ES, 1996a). The expanded system included two additional air injection VWs (VW2 and VW3), two additional VMPs (VMP4 and VMP5), an upgraded 3-horsepower blower system and housing, and associated piping, controls, and electrical service

(Figure 1). The expanded system VWs were screened from 10 to 40 feet bgs and the new VMPs were installed near the expected radius of influence of the VWs to evaluate vapor migration. Four casing strings and 6-inch screens were installed in each VMP boring at approximately 10, 24, 30, and 40 feet bgs. Soil and soil gas samples were collected for field and laboratory analysis prior to system startup to establish baseline conditions. The air injection flow rate for VW2 and VW3 was adjusted to approximately 10 cubic feet per minute (cfm) as this was judged as being sufficient to meet subsurface oxygen demand requirements (ES, 1993; AFCEE, 1996; Parsons ES, 1996b) while minimizing the potential for contaminant vapor migration.

In August 1996, following four weeks of air injection into VW2 and VW3, an additional set of soil gas samples was collected during expanded bioventing system operation to evaluate potential vapor migration from the areas of the site undergoing air injection for the first time. Initial results for the expanded bioventing system, along with an operations and maintenance manual and record drawings, and recommendations for extended system operation were provided by Parsons ES (1996b) to AFCEE and Beale AFB in December 1996. Parsons ES did not reestablish air flow to VW1, but recommended returning air flow to VW1 at approximately 10 cfm based on the low vapor migration indicated during the August 1996 sampling event.

Option 1 soil gas sampling and respiration testing was originally scheduled for August 1997 following 1 year of expanded bioventing system operation and 1-month of system shutdown. However, when Parsons ES contacted Beale AFB personnel to schedule the Option 1 field work, it was discovered that a respiration test was performed at the site in late June 1997 by Law Environmental. Parsons ES evaluated the results of the "area" respiration test performed by Law Environmental and determined a "point" respiration test following 1 month of system shutdown (similar to those performed initially and following 1-year of pilot-scale bioventing system operation) was more appropriate for the Option 1 test. System shutdown for 1 month prior to testing is necessary to allow site soil and soil gas to return to equilibrium conditions and allow comparison with previous site results. Blower shutdown and Option 1 field work were rescheduled for mid-February 1998 and mid-March 1998, respectively.

In March 1998, Parsons ES was informed by Beale AFB personnel that concentrations of *cis*-1,2-dichloroethene (*cis*-1,2-DCE), *trans*-1,2-DCE, and trichloroethene (TCE) had increased from 0.063 parts per million, volume per volume (ppmv), 0.0093 ppmv, and 0.016 ppmv to 68 ppmv, 15 ppmv, and 11 ppmv, respectively at the 10-foot bgs screened interval at VMP4 (VMP4-10) between the second and third quarter 1997 sampling events performed by Law Environmental. A review of the monitoring logs for the blower system indicates that the bypass valve which was used to bleed excess airflow to the atmosphere was closed and air injection was reestablished for VW1 in April 1997 (following the second quarter 1997 sampling event) (Law Environmental, 1997). As a result of the increased HVOC concentrations at VMP-4, and data obtained during recent/ongoing investigations of site soil vapor and groundwater, Beale AFB has determined that soil vapor extraction (SVE) treatment of site soil and soil vapor is necessary.

Parsons ES visited the site during the week of 16 March 1998 to perform Option 1 testing, but discovered that the blower system was running, and Option 1 testing could not be initiated. Airflow measurements confirmed that approximately 4 times the original flowrate of air was

being injected into VW2 and VW3 as a result of previous adjustments made to the system. In addition, the air flow rate into VW1 was almost 2 times higher than airflow into VW2 and VW3, and significantly exceeded recommended airflow rates for extended system operation (Parsons ES, 1996b). Following system measurements, Parsons ES shut down the blower system, locked out power to the blower and rescheduled field work for mid-April 1998. Parsons ES performed Option 1 soil gas sampling and respiration testing during the week of 13 April 1998. Soil gas sampling and *in situ* respiration testing results from this event represent site conditions following more than 3 years of pilot-scale bioventing system operation and 1 year and 9 months of expanded bioventing system operation. Results from this sampling event are summarized below, as are recommendations based on this data. It should be noted that following the Option 1 sampling event, the blower system at Site 11 was reconfigured for SVE by Laguna and Metcalf and Eddy, Inc., under contract to the Air Force and plumbed to a newly installed extraction well near the oil/water separator located south of VW3 (Figure 1). SVE system startup began in May 1998 and system operation and maintenance is being performed by CH2M Hill (Gaudette, 1998).

SOIL GAS CHEMISTRY RESULTS

Option 1 soil gas samples were collected from the VWs and VMPs at Site 11 on 13 and 14 April 1998. Samples were field-screened to assess soil gas concentrations of oxygen, carbon dioxide, and TVH and samples from VW1, VMP1-24, VMP2-24, and VMP3-24 were submitted for laboratory analysis of TVH and BTEX by USEPA Method TO-3. Soil gas samples from VMP4-10 and VMP4-24 were submitted for laboratory analysis of VOCs by USEPA Method TO-14. Table 1 summarizes field soil gas results and laboratory-determined concentrations of petroleum hydrocarbons in site soil gas from the Option 1 sampling event and previous sampling events. Table 2 summarizes the July 1996, August 1996, and April 1998 HVOC and non-petroleum hydrocarbon VOC results obtained by Parsons ES at VMP4.

During the Option 1 testing event, static oxygen concentrations in site soil gas generally were at or near atmospheric levels (20.9 percent) at the VWs and the deeper VMP screened intervals. For most of these locations, static oxygen concentrations in soil gas were not significantly depleted prior to initiation of expanded bioventing system operation. For the pilot-scale VMPs, VMP1, VMP2, and VMP3, the 24-foot depth interval continued to exhibit moderate oxygen utilization by soil microbes as static oxygen concentrations of 6.0 percent, 6.5 percent, and 14.1 percent, respectively, were measured. Compared to the deeper screened intervals at these VMPs, concentrations of TVH and carbon dioxide also continued to be elevated, further indicating the presence of residual hydrocarbon contamination and ongoing aerobic biodegradation. At VMP5-10, the static oxygen concentration was increased from 11.9 percent to 20.6 percent, as a result of more than 1 year of expanded bioventing system operation. During this same time period, the static oxygen concentration at VMP4-10 decreased and TVH concentrations increased. During initial monitoring activities following expanded system startup in July 1996, minimum pressure influence was observed at VMP4-10; however, it appears that the excessive air injection rates are likely the cause of increased vapor migration and decreased oxygen concentrations in soil gas at this location.

Analytical soil gas results for petroleum hydrocarbons detected during the April 1998 sampling event and previous sampling events are shown in Table 1. Low TVH concentrations and low/non-detect BTEX concentrations in soil gas samples collected from VMP1-24 and

VMP2-24, and VMP4-30 indicate that the petroleum hydrocarbon contamination in surrounding soils is minimal and has been successfully remediated by bioventing activities at the site. Concentrations of petroleum hydrocarbons in soil gas collected from VMP3-24 were further reduced during expanded bioventing system operation, but continue to be slightly elevated. At VMP4-10, elevated concentrations of hexane, heptane, and cyclohexane indicate vapor migration from surrounding soils with more significant soil contamination than was originally observed at VMP4 during monitoring point installation.

Table 2 summarizes analytical soil gas results for HVOCs and non-petroleum VOCs detected at VMP4. As indicated by the third quarter 1997 "dynamic" sampling event performed by Law Environmental, static VOC concentrations have increased significantly as compared to initial measurements. The primary HVOCs present in soils surrounding VMP4-10 appear to be TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride. These contaminants appear to have been mobilized from a nearby "pocket" of contamination by the excessive air injection flowrates created by improper adjustments to the expanded blower system.

RESPIRATION TEST RESULTS

As part of the Option 1 field effort, *in situ* respiration testing was performed at the site between 14 and 17 April 1998 in accordance with protocol procedures (Hinchee, *et al.*, 1992). Prior to the test, air was injected for approximately 21 hours into four VMPs (VMP1-24, VMP2-24, VMP3-24, and VMP4-10) using 1-cubic foot per minute pumps to locally oxygenate soils in the vicinity of these points. Following air injection, changes in oxygen, carbon dioxide, and TVH soil gas concentrations were monitored over a 48-hour period. Observed rates of oxygen utilization were then used to estimate aerobic fuel biodegradation rates at the site. Table 2 summarizes the respiration and fuel biodegradation rates determined during the April 1998 field event and compares them to rates determined during pilot-scale bioventing.

As is evident from Table 3, *in situ* respiration and fuel biodegradation rates have not decreased significantly with expanded bioventing system operation; however, average site rates 5 years after initiating bioventing activities are approximately half those observed in May 1993. Respiration testing at the site has been historically performed at the most contaminated soil intervals (24 to 30 feet bgs) and significant decreases have been observed in TVH and BTEX concentrations at these locations during more than 4 years of bioventing treatment. Relatively "flat" respiration and fuel biodegradation rates at these locations suggest that some aerobic biodegradation of residual petroleum hydrocarbon contaminants in soil is occurring, but at relatively low levels. Oxygen utilization and fuel biodegradation rates typically decrease with continued bioventing as the lighter, more readily biodegraded BTEX hydrocarbons, which typically present the majority of environmental site risk for petroleum hydrocarbons, are preferentially destroyed over more biologically recalcitrant, higher molecular weight hydrocarbons. Based on Option 1 field results and results obtained from previous sampling events, it appears that minimal BTEX contamination remains in site soils, and aerobic biodegradation of less mobile, less toxic, hydrocarbon contaminants is occurring at relatively low rates.

RECOMMENDATIONS

Results of soil gas sampling and respiration testing indicate that BTEX contamination in soils treated by the bioventing system has been effectively reduced to non-detect or near non-detect levels. While some petroleum hydrocarbon contamination is still evident in soils near VMP3-24 and VMP4-10, the contaminants are not present at excessive concentrations nor are they expected to pose significant site risk. Contaminated soils remaining in place following soil and UST excavation have been effectively remediated by pilot-scale and expanded bioventing system operation. Confirmation soil sampling (Option 2) is recommended to demonstrate that no further site investigation or remediation of petroleum hydrocarbons is necessary in this area. Elevated concentrations of total petroleum hydrocarbons in soil vapor collected near VW2 prior to 1996 (Parsons ES, 1995) also suggest that confirmation soil sampling may be warranted in this area.

Elevated HVOC concentrations at VMP4-10 appear to have resulted from excessive air injection rates caused by improper operation of the bioventing system, and advective transport of these contaminants away from the VWs. In essence, the blower system was being operated at airflow rates more consistent with SVE than bioventing and significant vapor migration may have occurred. Recent investigations at the site indicate that VOC contamination in site soil and groundwater primarily is a result of historic releases from the oil/water separators. An extraction well has been placed near VW3 and the bioventing blower system has been reconfigured for SVE. Operation of the SVE system began in May 1998.

If you have any questions or comments regarding this site, or the recommendations appearing in this report, please feel free to contact Mr. Michael Phelps at (510) 891-9085, or Mr. Craig Snyder or me at (303) 831-8100.

Sincerely,
PARSONS ENGINEERING SCIENCE, INC.

John Ratz, P.E.
Project Manager

cc: C. Gaudette (9 CES/CEVR, Beale AFB)
M. Phelps (Parsons ES - Oakland)
C. Snyder (Parsons ES - Denver)
File 726876.20110.E Letter Results Report

Attachments

REFERENCES

Air Force Center for Environmental Excellence (AFCEE). 1995. Completion of One Year Bioventing Test, Site 11. Memorandum for 9 CES/CEV, Ms. Carol Gaudette, Beale Air Force Base, California. 2 February.

AFCEE. 1996. A General Evaluation of Bioventing for Removal Actions at Air Force/Department of Defense Installations Nationwide, General Engineering Evaluation/Cost Analysis. Technology Transfer Division. June.

Beale AFB. 1998. Facsimile of IRP Site 11, Aerospace Ground Equipment Maintenance Area, figures from recent site investigations. From 9 CES/CEVR, Beale AFB, California to Craig Snyder, Parsons Engineering Science, Inc. June 16.

Engineering-Science, Inc. (ES) 1993. Part I, Bioventing Pilot Test Work Plan and Part II, Draft Interim Pilot Test Results Report for Aircraft Ground Equipment (AGE) Maintenance Area (Site 11), Beale Air Force Base, California. Alameda, California. October.

Gaudette, C. 1998. Personal Communication. 9 CES/CEVR, Beale Air Force Base, California. June 16.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frendt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing. January.

Law Environmental, Inc. 1995. Site Characterization Summary Informal Technical Information Report for Site 11, Beale Air Force Base, California (Draft). March.

Law Environmental, Inc. 1997. Third Quarter 1997 Monitoring Report, Sites 3, 10, 11, 18, and 22-A20, Biovent/SVE Systems, Beale Air Force Base, California.

Parsons Engineering Science, Inc. (Parsons ES). 1995. Work Plan for Expanded Bioventing System, Aircraft Ground Equipment (AGE) Maintenance Area, IRP Site 11, Beale Air Force Base, California. Alameda, California. December.

Parsons ES. 1996a. Letter and Enclosures to Lieutenant Maryann Jenner at AFCEE/ERT, Subject: Construction Drawings for the Extended Bioventing Treatability Test (Option 4) at IRP Site 11, Aircraft Ground Equipment Maintenance Area, Beale Air Force Base, California. Denver, Colorado. 11 January.

Parsons ES. 1996b. Letter Results Report to Major Marchand at AFCEE/ERT, Subject: Operations and Maintenance Manual, Record Drawings, and Summary of Initial Results for Expanded Bioventing System at Installation Restoration Program (IRP) Site 11, Beale Air Force Base, California. Oakland, California. 31 December.

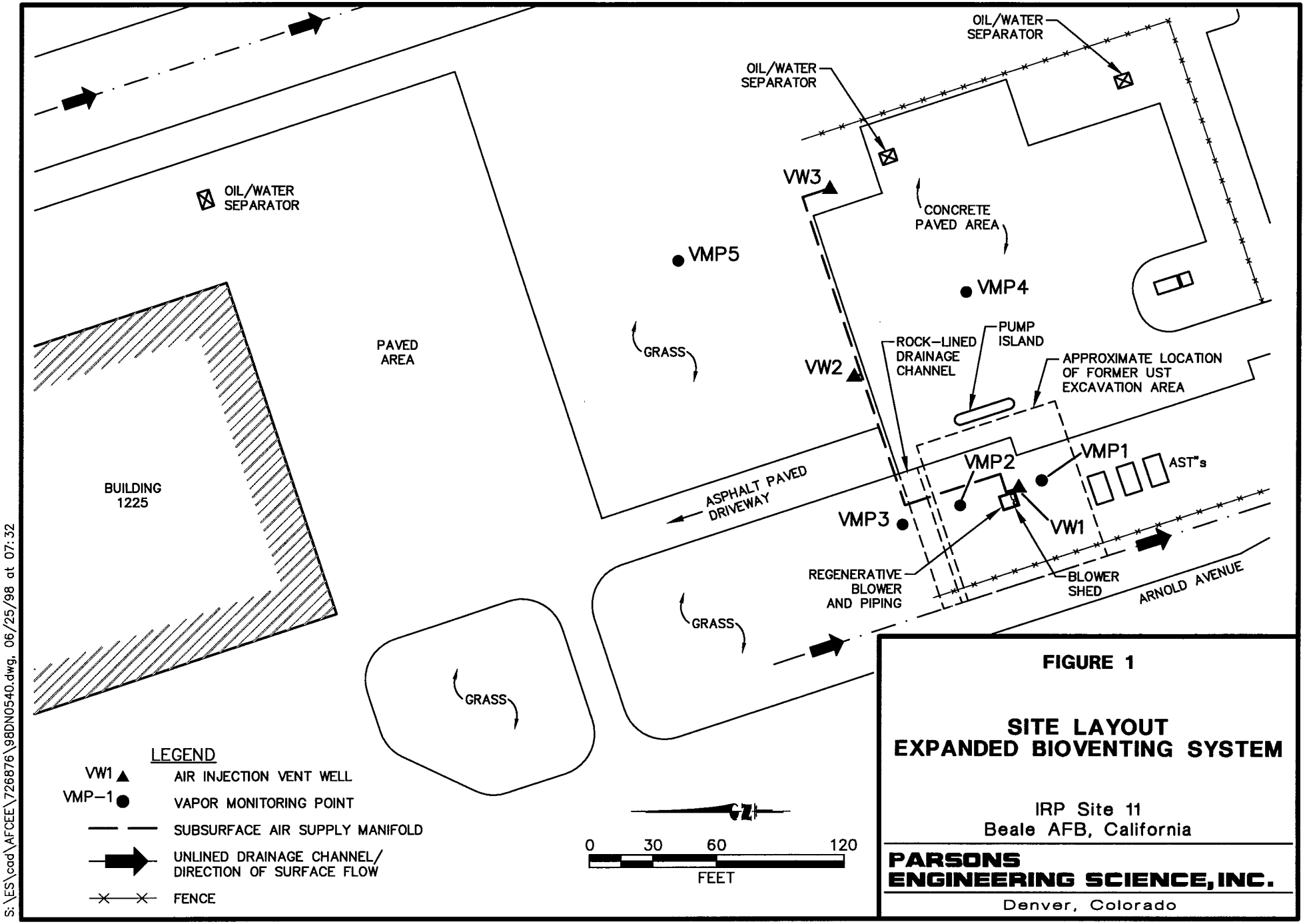

FIGURE 1

SITE LAYOUT EXPANDED BIOVENTING SYSTEM

IRP Site 11
Beale AFB, California

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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TABLE 1
SUMMARY OF FIELD AND PETROLEUM HYDROCARBON ANALYTICAL SOIL GAS RESULTS
IRP SITE 11
BEALE AFB, CALIFORNIA

Sample Location	Depth (feet bgs)[a/]	Sampling Event[b/] (Date)	Field-Screening Data: Oxygen (percent)	Carbon Dioxide (percent)	TVH[c/] (ppmv)[d/]	Laboratory Data[e/]: TVH[f/] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)	Hexane (ppmv)	Heptane (ppmv)	1,2,4-TMB[g/] (ppmv)	1,3,5-TMB[g/] (ppmv)	4-Ethyltoluene (ppmv)	Cyclohexane (ppmv)
PILOT-SCALE BIOVENTING SYSTEM COMPONENTS																
VW1	10-50	Initial (5/93)	2.0	8.0	9,600	51,000	30	74	13	310	--[h/]	--	--	--	--	--
		1-Year (7/94)	20.5	0.6	96	7.4	0.008	[redacted]	0.006	0.12	--	--	--	--	--	--
		3-Year (7/96)	19.9	0.3	12	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	19.7	0.7	0	6.5	[redacted]			0.051	--	--	--	--	--	--
VMP1	24	Initial (5/93)	3.0	11.0	>10,000[j/]	72,000	430	550	40	240	--	--	--	--	--	--
		1-Year (7/94)	10.0	3.2	1,200	3,500	1.2	12	10	140	--	--	--	--	--	--
		3-Year (7/96)	7.5	3.3	105	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	6.0	3.9	100	37	[redacted]	0.022	0.044	0.25	--	--	--	--	--	--
	30	Initial (5/93)	2.8	7.5	>10,000	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	19.0	0.7	66	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	20.0	0.5	10	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	20.0	0.7	25	--	--	--	--	--	--	--	--	--	--	--
	40	Initial (5/93)	3.0	7.0	>10,000	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	18.5	0.6	36	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	19.0	0.5	10	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	19.0	0.9	30	--	--	--	--	--	--	--	--	--	--	--
VMP2	24	Initial (5/93)	2.0	6.8	>10,000	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	9.5	3.0	4,400	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	9.5	3.5	260	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	6.5	6.0	100	37	[redacted]	0.037	0.041	0.23	--	--	--	--	--	--
	30	Initial (5/93)	3.5	7.2	>10,000	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	19.0	0.6	300	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	19.0	0.3	28	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	20.4	0.6	10	--	--	--	--	--	--	--	--	--	--	--
	40	Initial (5/93)	3.0	6.6	>10,000	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	17.8	0.8	780	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	19.5	0.8	70	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	19.9	0.7	20	--	--	--	--	--	--	--	--	--	--	--
	50	Initial (5/93)	2.2	6.2	7,800	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	14.9	2.9	1,900	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	17.5	2.0	110	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	18.3	1.9	70	--	--	--	--	--	--	--	--	--	--	--

TABLE 1 (continued)
SUMMARY OF FIELD AND PETROLEUM HYDROCARBON ANALYTICAL SOIL GAS RESULTS
IRP SITE 11
BEALE AFB, CALIFORNIA

			Field-Screening Data			Laboratory Data[e/]										
Sample Location	Depth (feet bgs)[a/]	Sampling Event[b/] (Date)	Oxygen (percent)	Carbon Dioxide (percent)	TVH[c/] (ppmv)[d/]	TVH[f/] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)	Hexane (ppmv)	Heptane (ppmv)	1,2,4-TMB[g/] (ppmv)	1,3,5-TMB[g/] (ppmv)	4-Ethyltoluene (ppmv)	Cyclohexane (ppmv)
VMP3	24	Initial (5/93)	1.0	6.6	2,000	55,000	580	970	59	350	--	--	--	--	--	--
		1-Year (7/94)	11.8	3.4	2,100	4,900	2.7	26	12	390	--	--	--	--	--	--
		3-Year (7/96)	12.0	3.0	1,100	4,200	[redacted]			150	[redacted]		340	190	170	[redacted]
		3.1-Year (8/96)[k/]	17.5	2.0	1,000	3,600	0.89	[redacted]		62	2.7	[redacted]	170	99	61	
		5-Year (4/98)	14.1	3.7	550	1,300	[redacted]	0.17	0.63	14	--	--	--	--	--	--
	30	Initial (5/93)	1.5	7.8	9,200	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	18.0	0.7	500	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	18.5	0.5	53	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	20.4	0.6	5	--	--	--	--	--	--	--	--	--	--	--
	40	Initial (5/93)	1.6	5.8	5,600	--	--	--	--	--	--	--	--	--	--	--
		1-Year (7/94)	18.2	0.6	100	--	--	--	--	--	--	--	--	--	--	--
		3-Year (7/96)	18.5	0.3	16	--	--	--	--	--	--	--	--	--	--	--
		5-Year (4/98)	20.4	0.6	10	--	--	--	--	--	--	--	--	--	--	--
EXPANDED BIOVENTING SYSTEM COMPONENTS																
VW2	10-40	Initial (7/96)	20.5	0.3	200	52/28[j/]	0.28/0.069	0.26/0.055	[redacted]	0.88/0.79	[redacted]		0.17/0.30	0.40/0.33	0.32/0.36	[redacted]
		1.75-Year (4/98)	20.4	0.6	0	--	--	--	--	--	--	--	--	--	--	--
VW3	10-40	Initial (7/96)	20.8	0.0	2	5.3	0.0058	0.0021	[redacted]	0.0101	[redacted]		0.0032	[redacted]	0.0047	[redacted]
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--	--	--	--	--	--
VMP4	10	Initial (7/96)	18.0	1.9	190	99/150	0.048/0.100	[redacted]			5.6/7.0	[redacted]				
		1-month (8/96)[k/]	16.5	2.8	1,000	1,200	0.23				10	3.7	0.078	0.049	[redacted]	
		1.75-Year (4/98)	3.7	9.2	9,000	[redacted]					250/280	65/76	[redacted]			440/500
	24	Initial (7/96)	19.5	0.8	46	--	--	--	--	--	--	--	--	--	--	--
		1.75-Year (4/98)	19.0	1.0	50	[redacted]				0.0051	0.086	0.025	0.0053	0.015	[redacted]	0.160
	30	Initial (7/96)	20.8	0.0	290	[redacted]										
		1-month (8/96)[k/]	20.6	0.3	14	0.66	[redacted]						0.0048	0.0016	[redacted]	
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--	--	--	--	--	--
	40	Initial (7/96)	20.8	0.3	66	--	--	--	--	--	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--	--	--	--	--	--
VMP5	10	Initial (7/96)	11.9	4.5	74	1.8	0.0038	0.0012	[redacted]				0.0010	[redacted]		
		1-month (8/96)[k/]	16.8	>5.0	100	0.072	[redacted]	0.00078					0.0011			
		1.75-Year (4/98)	20.6	0.8	16	--	--	--	--	--	--	--	--	--	--	--
	24	Initial (7/96)	20.8	0.3	100	--	--	--	--	--	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--	--	--	--	--	--
	30	Initial (7/96)	20.8	0.3	94	--	--	--	--	--	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--	--	--	--	--	--
	40	Initial (7/96)	20.8	0.3	16	--	--	--	--	--	--	--	--	--	--	--
		1.75-Year (4/98)	20.8	0.5	0	--	--	--	--	--	--	--	--	--	--	--

TABLE 1 (continued)
SUMMARY OF FIELD AND PETROLEUM HYDROCARBON ANALYTICAL SOIL GAS RESULTS
IRP SITE 11
BEALE AFB, CALIFORNIA

			Field-Screening Data			Laboratory Data[e/]										
Sample Location	Depth (feet bgs)[a/]	Sampling Event[b/] (Date)	Oxygen (percent)	Carbon Dioxide (percent)	TVH[c/] (ppmv)[d/]	TVH[f/] (ppmv)	Benzene (ppmv)	Toluene (ppmv)	Ethylbenzene (ppmv)	Xylenes (ppmv)	Hexane (ppmv)	Heptane (ppmv)	1,2,4-TMB[g/] (ppmv)	1,3,5-TMB[g/] (ppmv)	4-Ethyltoluene (ppmv)	Cyclohexane (ppmv)

[a/] Sample depth in feet below ground surface.
[b/] Sampling events identified based upon approximate time since pilot-scale and expanded-scale bioventing began in May 1993 and July 1996, respectively.
[c/] TVH = Total volatile hydrocarbons.
[d/] ppmv = Parts per million, volume per volume.
[e/] Laboratory analysis of soil gas performed using either USEPA Method TO-3 or USEPA Method TO-14.
[f/] TVH referenced to jet fuel and gasoline when analyzed by Method TO-3 and Method TO-14, respectively.
[g/] TMB = Trimethylbenzene.
[h/] -- = Not analyzed.
[i/] < and gray shading = Compound analyzed for, but not detected. Number shown represents the laboratory reporting limit.
[j/] > = Concentration greater than maximum reading on field instrument.
[k/] System operating during sampling event; results represent "dynamic" conditions 1 month following expanded bioventing system startup.
[l/] Original sample result/duplicate result.

TABLE 2
VOC ANALYTICAL SOIL GAS RESULTS AT VMP4
IRP SITE 11
BEALE AFB, CALIFORNIA

Analyte[a/]	Units[b/]	VMP-4-10					VMP-4-24	VMP-4-30	
		Jul-96	Dup[c/].(Jul-96)	Aug-96[d/]	Apr-98	Dup.(Apr-98)	Apr-98	Jul-96	Aug-96[d/]
Halogenated VOCs									
PCE	(ppmv)	<0.021[e/]	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
TCE	(ppmv)	0.32	[0.37]	1.2	10	[11]	0.0047	<0.036	<0.0012
cis-1,2-DCE	(ppmv)	1.2	[1.4]	2.6	57	[65]	0.024	<0.036	<0.0012
trans-1,2-DCE	(ppmv)	0.22	[0.30]	1.2	13	[15]	0.0054	<0.14	<0.0046
Vinyl Chloride	(ppmv)	0.078	[0.10]	<0.049	4.6	[5.4]	0.0016	<0.036	<0.0012
1,1,1-TCA	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	0.037	<0.0012
1,1-DCE	(ppmv)	<0.021	[<0.0090]	0.069	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
1,2-DCA	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Chloroform	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Methylene Chloride	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Freon 12	(ppmv)	<0.021	[<0.0090]	<0.049	<0.990	[<1.2]	<0.00081	<0.036	<0.0012
Other VOCs									
Propylene	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.029	<0.14	<0.0046
Acetone	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.0049	<0.14	<0.0046
Carbon Disulfide	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046
2-Propanol	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046
Tetrahyrdrofuran	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.013	<0.14	<0.0046
1,4-Dioxane	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	0.0034	<0.14	<0.0046
2-Hexanone	(ppmv)	<0.082	[<0.036]	<0.190	<3.9	[<4.7]	<0.0032	<0.14	<0.0046

[a/] PCE = tetrachloroethene (perchloroethene); TCE = trichloroethene; DCE = dichloroethene; TCA = trichloroethane; DCA = dichloroethane.

[b/] ppmv = parts per million, volume per volume.

[c/] Dup = duplicate; results shown in brackets.

[d/] System operating during sampling event; results represent "dynamic" conditions 1 month following expanded bioventing system startup.

[e/] < and gray shading = Compound analyzed for, but not detected. Number shown represents the laboratory reporting limit.

TABLE 3
SUMMARY OF RESPIRATION AND FUEL BIODEGRADATION RATES
IRP SITE 11
BEALE AFB, CALIFORNIA

Location-Depth (feet below ground surface)	Initial (May 1993)		6-Month (December 1993)[b/]		1-Year (July 1994)		5-Year (April 1998)[b/c/]	
	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)[a/]	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)	Respiration Rate ($\%O_2$/hour)	Degradation Rate (mg/kg/year)
VMP1-24	0.12	50	0.039	47	0.036	71	0.14	180
VMP2-24	0.047	130	0.038	110	0.023	63	0.034	100
VMP3-24	NS[d/]	NC[e/]	NS	NC	NS	NC	0.034	100
VMP3-30	0.18	530	0.016	47	0.039	110	NS	NC
VMP4-10	NA[f/]	NA	NA	NA	NA	NA	0.060	180

[a/] Milligrams of hydrocarbons per kilogram of soil per year.

[b/] Assumes moisture content of the soil is average of initial and 1-year moistures.

[c/] 5-year testing event represents approximate time since initial testing in May 1993, not necessarily the cumulative bioventing treatment time.

[d/] NS = not sampled.

[e/] NC = not calculated; degradation rates cannot be estimated without respiration rate data.

[f/] NA = not applicable; VMP4 installed in July 1996 as part of the expanded-scale bioventing system.